

It has long been known that the disease is most common in the dirty, ill-drained, ill-ventilated dwellings of the poor, and, even in records intended to prove the contagiousness of phthisis, there are few, if any, of transmission of the disease in clean, well-lighted, well-ventilated houses or hospitals, even those for consumption. Long before Koch's discoveries, and before the disinfection of sputum was practised as it is now, the conveyance of the disease, under these conditions, was recognised by many to be one of the rarest events.

If the results that we have obtained with sputum are confirmed by others, as we trust they will be, they will afford some explanation of these facts.

So far as they extend at present, they show (1) that finely divided tuberculous matter, such as pure cultures of the bacillus, or "tuberculous dust," in daylight, and in free currents of air, is rapidly deprived of virulence, (2) that even in the dark, although the action is retarded, fresh air has still some disinfecting influence, and (3) that in the absence of air, or in confined air, the bacillus retains its power for long periods of time.\*

VI. "On some Voltaic Combinations with a Fused Electrolyte and a Gaseous Depolariser." By J. W. SWAN, M.A. Communicated by LORD RAYLEIGH, Sec. R.S. Received February 28, 1894.

It is well known that fused salts behave in many respects like electrolytes in solution, and that voltaic combinations analogous to well-known voltaic cells may be formed with fused electrolytes.

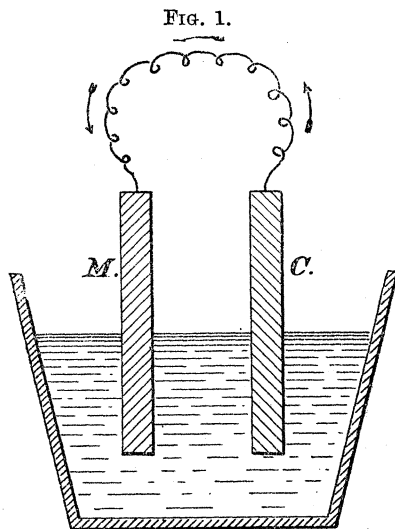
The experiments of Brown† have recently illustrated this subject in relation to the Daniell type of cell. For various reasons it appeared to the writer desirable to ascertain the behaviour of a cell with fused electrolyte and a gaseous depolariser, and corresponding in this last particular to the Upward cell.

The following is chiefly a record of some of the experiments made in connection with this research.

A cell of this kind may be looked at from a theoretical point of view as follows:—A rod of metal, M (fig. 1), is immersed in a fused chloride of the same metal, MCl, and a chemically inactive conductor, C, is also immersed in the fused salt; when M and C are connected with an electrostatic volt-meter, the metallic chloride is immediately

\* A portion of the expenses of this research has been defrayed by a grant from the British Medical Association.

† 'Roy. Soc. Proc.' vol. 52, pp. 75—91.

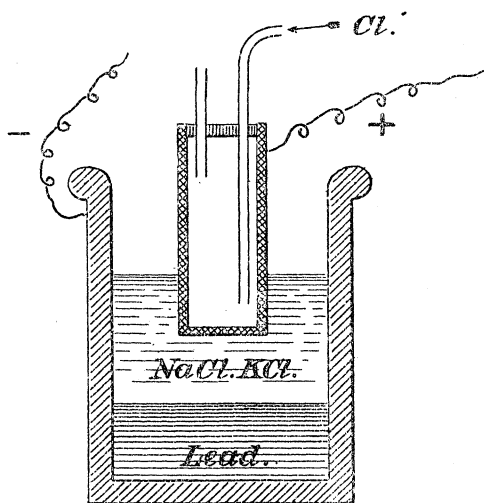


polarised, and an E.M.F. calculable from the heats of combination,  $M/Cl = MCl$ , is developed. If M and C are metallically connected, a momentary current passes, but the combination is immediately polarised by the opposing couple, formed by the cation of the electrolyte M and the pole C. To prevent this polarisation, chlorine has to be supplied at this pole. Complete depolarisation should occur if the pole C consisted of a solid rod of chlorine. This is impossible, but gaseous chlorine, used as a depolariser, can be made to effect more or less complete depolarisation, and should, theoretically, yield as the result of its heat of combination with lead an E.M.F. of 1.7942 volts. In experiments made with a view to realise as nearly as possible the ideal condition for preventing polarisation the cathode was always molten lead. It was found that hard gas-retort carbon had very little action upon molten alkaline chlorides and on chloride of lead, at the temperature required for their fusion. Carbon was, therefore, employed as the anode or conducting pole in most of the combinations.

The electrolyte used was either the molten chlorides of sodium and potassium mixed, or chloride of lead. As there is a continuous formation of  $PbCl_2$  during the action of the cell, and as it is a good conductor, it alone was finally adopted as the electrolyte. As a depolariser, chlorine gas was used. Many experiments were made to find a suitable way of applying the chlorine. The following are details of some of the most suggestive of them.

*Exp. 1.*—A cell was constructed as shown in fig. 2. The arrangement consists of an outer iron vessel, with a stratum of molten lead

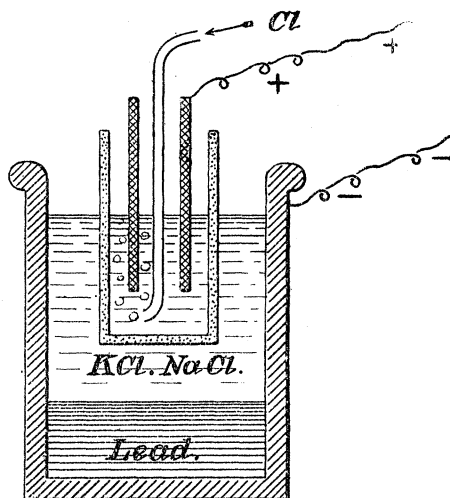
FIG. 2.



covering the bottom to some depth, over the lead is a layer of NaCl and KCl previously fused, into which is immersed the lower and closed end of a carbon tube, which forms the + pole. The mouth of the carbon tube is closed by a fire-clay lid luted on, and through which pass two small clay tubes for the inlet and outlet of chlorine. The whole was heated in a small gas furnace. A binding screw on the iron vessel, which served as a connection with the lead, was used as the negative terminal, and another screw fixed on a copper ring surrounding the carbon tube, served as the positive pole connection. The first trial was made without chlorine. Short circuited through 1,000 ohms the cell developed an E.M.F. of 0.3 volt. A momentary current of more than one ampère was observed when the cell was short circuited through a low resistance ammeter. Chlorine was then passed through the tubes inside the carbon pole, but *no depolarising effect* was observed, even when the chlorine had a slightly higher pressure than the atmosphere, yet the gas passed through the exposed sides of the carbon tube and through the cement at the top. This experiment was repeated several times with carbon tubes of the smallest possible thickness, and always with the same result. It is evident, therefore, that an absorption of chlorine similar to that which takes place in the Upward cell does not occur when a molten electrolyte of the kind employed in this experiment is used.

*Exp. 2.*—As this method of applying chlorine was unsuccessful, another form of apparatus was adopted. The poles were of the same material as in the previous experiment, but the carbon pole

FIG. 3.



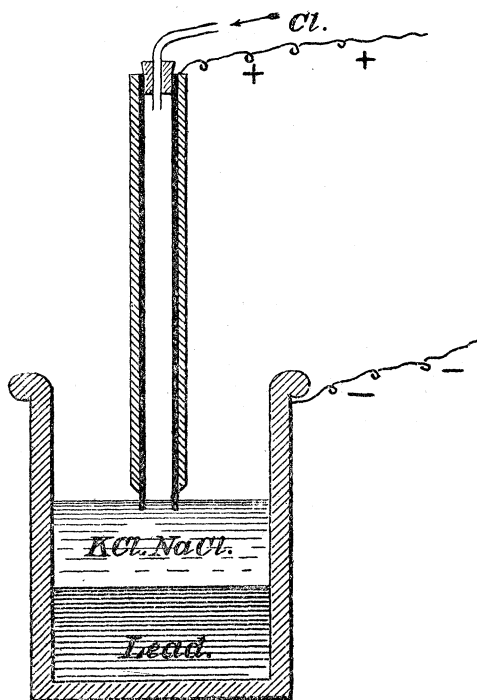
was an open tube. The electrolyte was a fused mixture of equivalent proportions of  $\text{NaCl}$ ,  $\text{KCl}$ . A porous pot was introduced in order to separate the products of electrolysis set free at the electrodes. The chlorine gas was supplied through a clay tube, which passed down the centre of the carbon tube. As before, an iron crucible was used as the containing vessel for the fused lead and the electrolyte, it also served as a means of electrical connection with the lead. In relation to the depolarisation effect of the chlorine, which it was the principal object of the experiment to observe, the interfering action of the iron was found by comparison with porcelain to be practically *nil*; this no doubt is a consequence of its becoming coated by local action with a film of lead. The whole arrangement was heated in a reverberatory furnace. When the electrolyte was perfectly fused, the element was short circuited through a volt-meter of 1000 ohms resistance. An E.M.F. of 0.3 volt was observed, the outside current being from the carbon to the lead. This was the E.M.F. after polarisation. A current of chlorine was then passed through the earthenware tube; while the current of gas was slow there was no effect, but when the speed of the issuing gas was increased until the gas passed in bubbles along the side of the carbon, alternately surrounding it with chlorine and electrolyte, the E.M.F. rose to 1.25 volt. The action of the cell was then similar to a completely depolarised cell. When short circuited through a low resistance ammeter, it produced a steady current of 1.0 ampère for three-quarters of an hour. The potential difference between the poles was of course very small, while this current was passing, the exterior resistance being very small com-

pared with the interior. When, however, the circuit was opened, it almost instantly rose to 1.25 volt.

So far the experiments showed that, as chlorine is nearly or perfectly insoluble in fused chloride of lead, or in fused chlorides of sodium and potassium, *it is necessary in this case that the surface of the carbon pole on which the cathion is deposited be alternately exposed to the action of the gas and electrolyte.* Many experiments confirmed this conclusion. The exposed surface of the carbon tube in this experiment amounted to only 10 or 12 sq. cm.

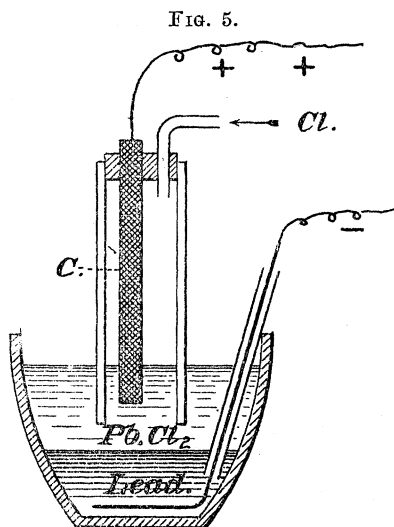
*Exp. 3.*—As in the arrangement last described, the use of a porous pot and a clay tube was found to be objectionable, through the action of the electrolyte upon them, an arrangement was devised by which the use of the porous pot and tube were avoided. The details are seen in fig. 4. The carbon tube serves as an electrode, and also for conveying the chlorine to the electrolyte. To render it impervious to the gas, it was surrounded by a close-fitting porcelain tube. This tube was closed at the top by a paraffined cork, through which a glass tube in connection with the chlorine supply was passed. The remainder of the apparatus was the same as in Experiment 2, but

FIG. 4.



without the porous pot. This arrangement gave the following results. The E.M.F. when short-circuited through a voltmeter (300 ohms) gave 1.4 volt, the chlorine entering rapidly. When short-circuited through 1 ohm, it gave a constant current of 0.6 ampère with a P.D. of 0.9 volt. The rather large interior resistance of 1.3 ohm is due not to the electrolyte, but to the greater length of the carbon tube, and bad contacts produced by the corrosive action of the chlorine. No good results were obtained until the chlorine gas bubbled out of the carbon tube, thus realising the conditions before mentioned, as necessary for the production of any large electrical effects.

*Exp. 4.*—With a view to obtain larger effects, another form of cell was tried, as shown in fig. 5. The carbon pole C consisted of a thin rod of electric light carbon, 5 mm. diameter and 15 cm. long. It was passed

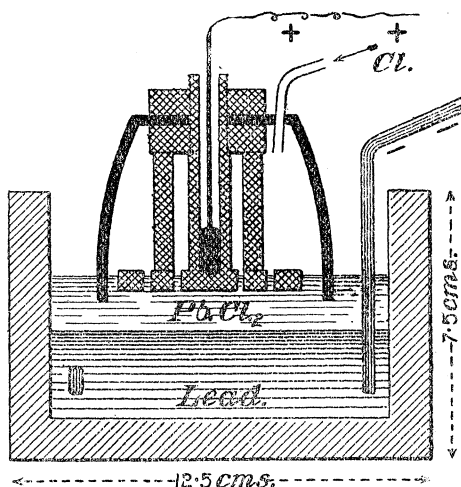


through a cork fitted in a porcelain tube, 2.5 cm. diameter. A glass tube bent at right angles was passed through the same cork, to serve for the delivery of the chlorine. The end of the carbon rod was a little short (about 3 mm.) of the end of the porcelain tube. The containing vessel was a Berlin porcelain crucible, 7 cm. diameter. The conductor from the lead was an iron wire, protected from the action of the electrolyte by a surrounding porcelain tube. The electrolyte was chloride of lead. The whole was arranged as shown in fig. 5. When the chlorine issued from the porcelain tube, the necessary conditions for depolarisation were in a large degree realised, the contact between the electrolyte and the carbon being at times almost broken,

and at other times the chlorine forming a nearly complete envelope round the carbon, these conditions following in rapid alternation. The highest E.M.F. observed was 1.25 volt. The largest current given was 0.9 ampère with a P.D. of 0.25 volt. The current was fluctuating, owing to the varying conditions at the carbon pole.

*Exp. 5.*—The following figure shows a construction almost identical with the last, differing only in a few practical details, occasioned by this cell being made larger than the last. The porcelain tube previously used was replaced by an inverted porcelain crucible, having two holes drilled in the bottom; the larger hole afforded a passage for the conductor from the carbon pole: through the smaller one there passed a porcelain pipe for the chlorine supply. The carbon pole was composed of a disc of gas retort carbon, pierced with holes, as shown in the figure. In the middle of the disc was screwed a tube of carbon, which passed up through the larger hole in the bottom of the crucible and was secured in this position by nuts of retort carbon. The bottom of the carbon tube was filled with fused lead, into which dipped a thick copper wire that formed the positive pole connexion.

FIG. 6.



The connexions between the carbon and porcelain were luted with a mixture of borax and fire-clay fused at a bright red heat. The other vessel consisted of a short cylindrical plumbago crucible. The fused lead was, as usual, on the bottom, connexion being made with it by means of a heavy open iron ring, with its free end turned up and bent over the rim of the crucible. The internal resistance was small, owing to the improved contact of the leading wire with the carbon

pole. The electrolyte was fused  $\text{PbCl}_2$ . The whole was heated in a gas furnace. When the electrolyte was fused, the chlorine was passed rapidly through, so that it issued from under the porcelain crucible. The E.M.F. was then between 0.94 and 0.96 volt., and never rose higher than 0.98 volt. The lower E.M.F. was evidently due to the fact that part of the surface of the carbon pole was not subject to the action of the chlorine, but remained polarised by deposition of lead. The behaviour was much like that of a constant cell with an E.M.F. of between 0.94 and 0.96 volt. The method of observation was to alter the exterior resistance and then read the current and P.D., then break the circuit and read the E.M.F.

P.D. (In closed circuit). Volt.	<i>y</i> . Ampères.	Calculated internal resistance.	
		$\frac{\text{E.M.F.}}{y}$	$-\frac{\text{P.D.}}{y}$ (calculated).
0.26	12.0		0.06
0.24	10.0		0.07
0.62	4.0		0.08
0.76	1.26		0.16
0.72	1.75		0.14
0.72	2.15		0.12
0.66	2.50		0.12

From these observations it will be seen that the internal resistance was calculated, col. 3, in order to find whether polarisation is greatest when a small or large current is taken from the cell. From the results it is apparent that the internal resistance, and at the same time the polarisation, *decrease* when the current *increases*. This kind of cell, therefore, differs from those in which aqueous electrolytes are used, inasmuch as the polarisation decreases with increased electrical output. The observations of P.D. and E.M.F. were taken almost simultaneously, and the variation of resistance as the gas bubbles passed out was thus avoided. As the internal resistance was very small the whole time, and remained almost constant during a variation of the current from 1.26 to 2.5 ampères, it may be said to be a constant battery, with an E.M.F. lower than the theoretical value. The reason of this lower E.M.F. is probably due to some part of the large carbon plate being covered with reduced lead, thus forming an opposing couple of smaller capacity and lower resistance than the primary elements, its effect being 'to reduce the main current. The E.M.F. of this opposing couple is of necessity the same as that of the main current, but, owing to its lower internal resistance, its P.D. is less; if it were not so, the cell would yield no appreciable current. This reasoning explains why the results obtained with small cells were better than those obtained with large ones.

Besides the experiments mentioned, trials have been made, with



more or less success, of many other forms of this combination, including some in which very porous hollow carbon poles were used, and through which the chlorine was forced, but the effects obtained were less than those recorded. The research has proved that it is possible to form pyro-batteries of the Upward type, although it is extremely difficult to realise the conditions required for effective action. In a future communication I hope to record the results of experiments made, with a view to utilise oxygen as a depolariser in connexion with cells with fused electrolytes.

VII. "Measurements of the Absolute Specific Resistance of Pure Electrolytic Copper." By J. W. SWAN and J. RHODIN.  
Communicated by Lord RAYLEIGH, Sec. R.S. Received  
February 28, 1894.

At the beginning of 1893 it was resolved to make some very careful measurements of the specific resistance of pure electrolytic copper, drawn into wire without previous fusion. Researches made during the latter end of 1892 had shown that the specific resistance of electrolytic copper varies considerably. The resistance of about thirty wires of the same length and diameter, made from specimens of electrolytic copper, prepared in different ways in the laboratory, showed differences of resistance amounting to a maximum of 1·4 per cent., both when in a hard and when in a soft or annealed state, and measured at the same temperature.

These preliminary measurements were made by means of a Wheatstone's bridge, constructed for comparing the unknown resistances of short well-conducting wires with the resistance of a standardised platinoid wire, according to Thomson's method. The accuracy obtainable by this method was 0·25 per cent. The best specimens of wire were subjected to a further and still more accurate examination.

The measurements of the specific resistance and temperature coefficient of one of these wires, and of some wire made from the same copper, after undergoing a second electrolytic refining, form the subject of this paper. It was resolved to make measurements giving an ultimate accuracy of 0·1 per cent. As they were intended to be absolute, the first problem was the determination of the exact dimensions of the wires to be measured. The measurement of the length was made by means of direct comparison with a standard metre rule; that of the diameter was determined by the specific gravity method, which consists in finding the absolute weight of a known length of wire and its density or unit volume weight as determined from its specific gravity, and then calculating its average diameter.

FIG. 1.

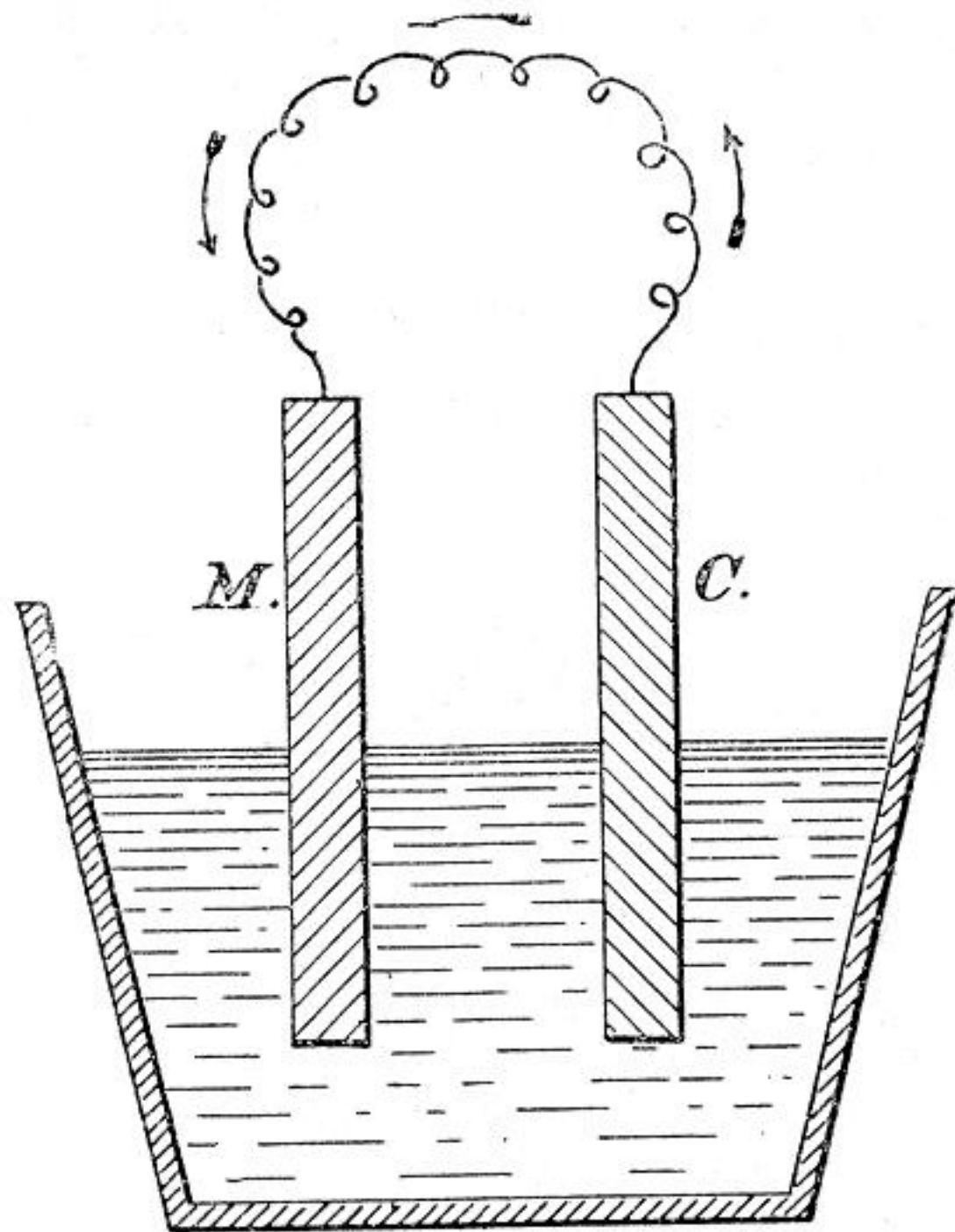


FIG. 2.

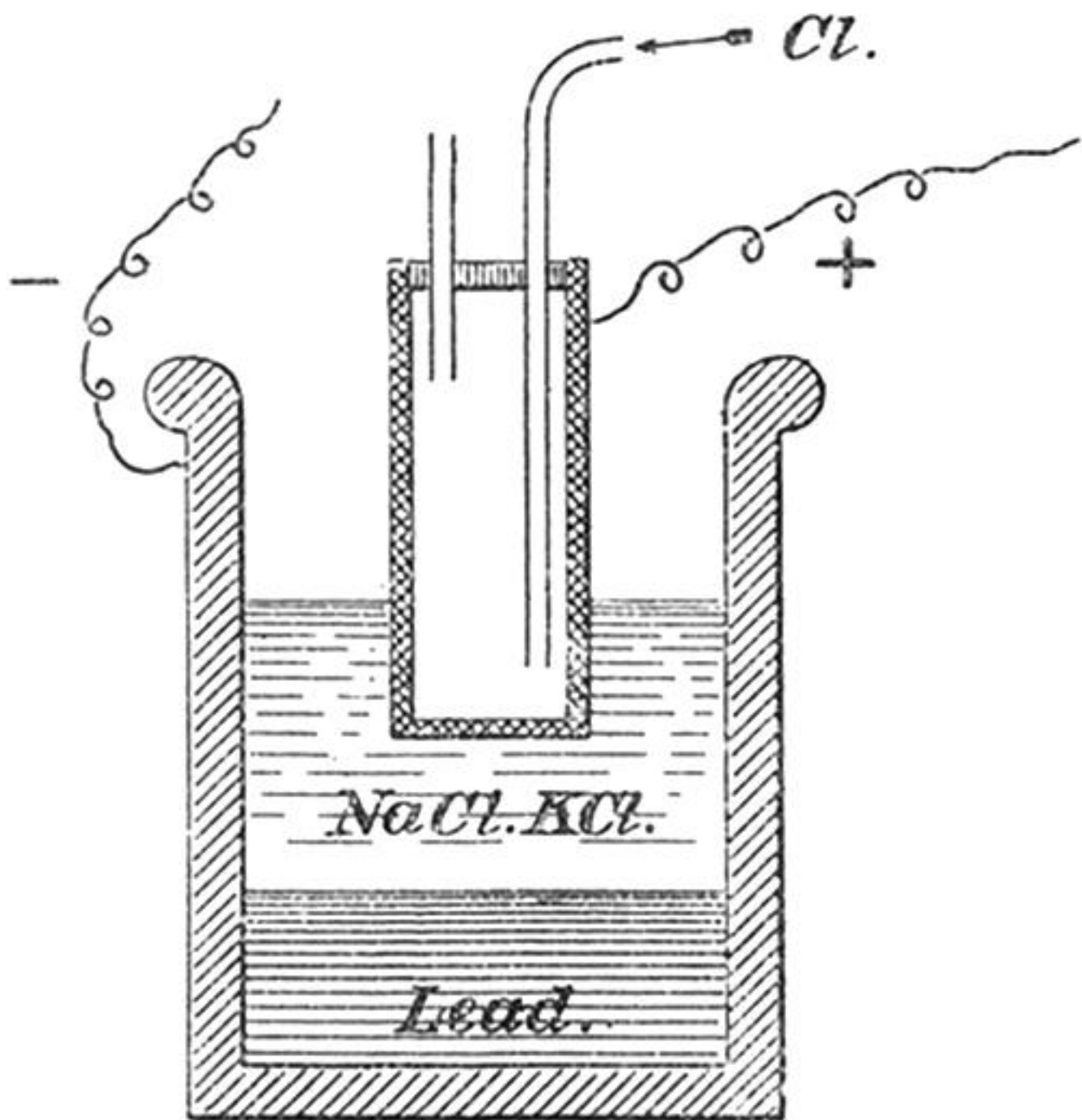


FIG. 3.

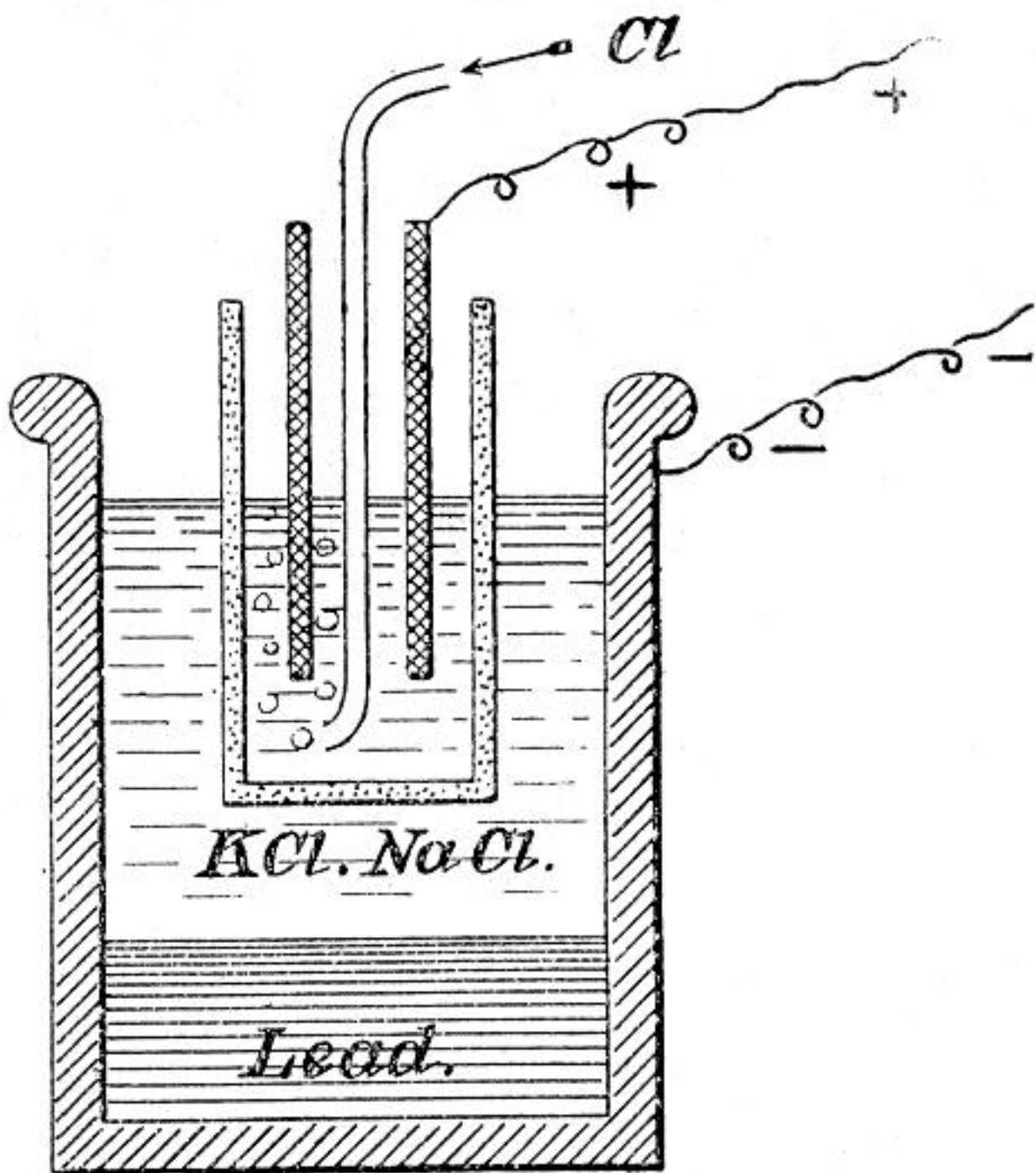


FIG. 4.

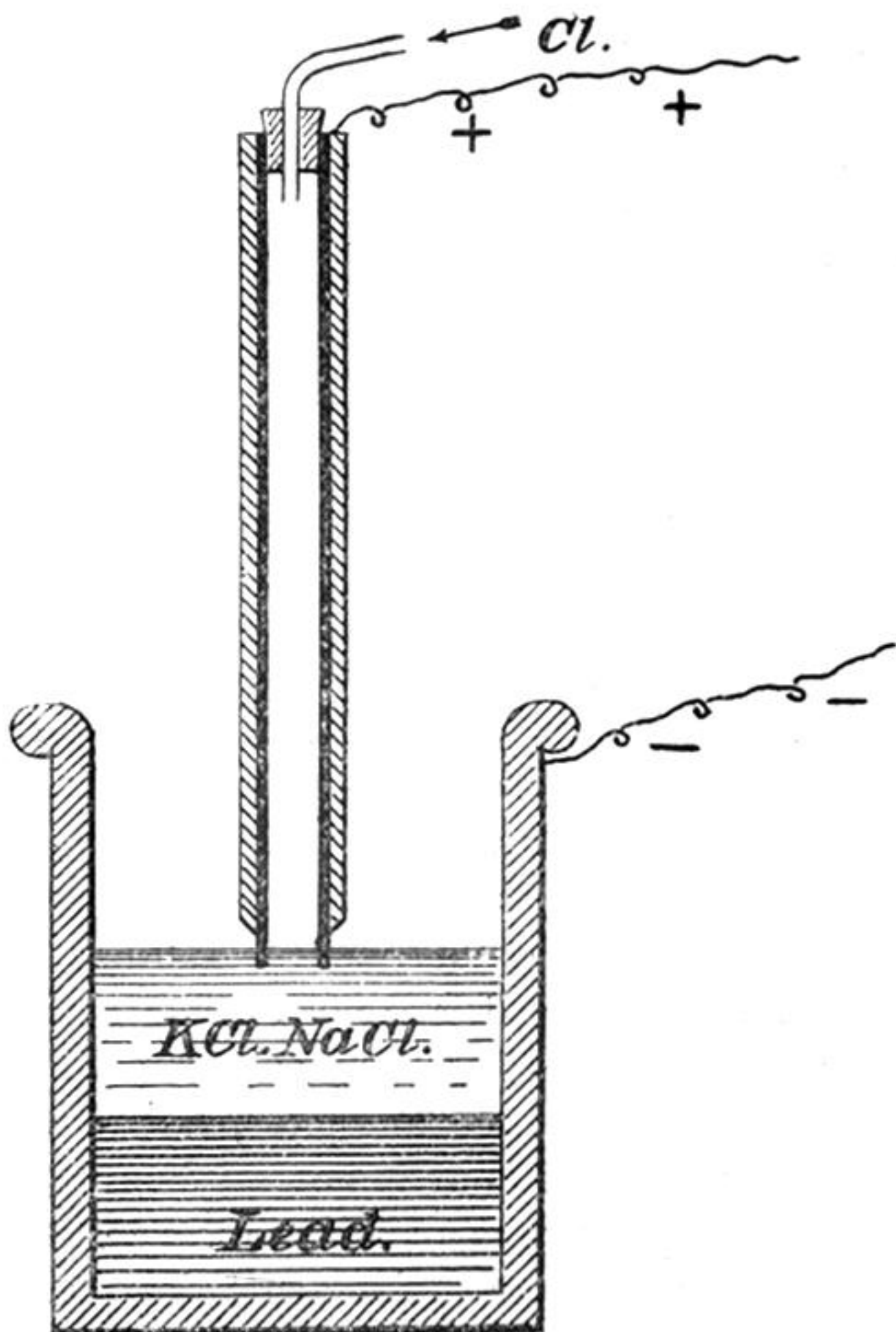


FIG. 5.

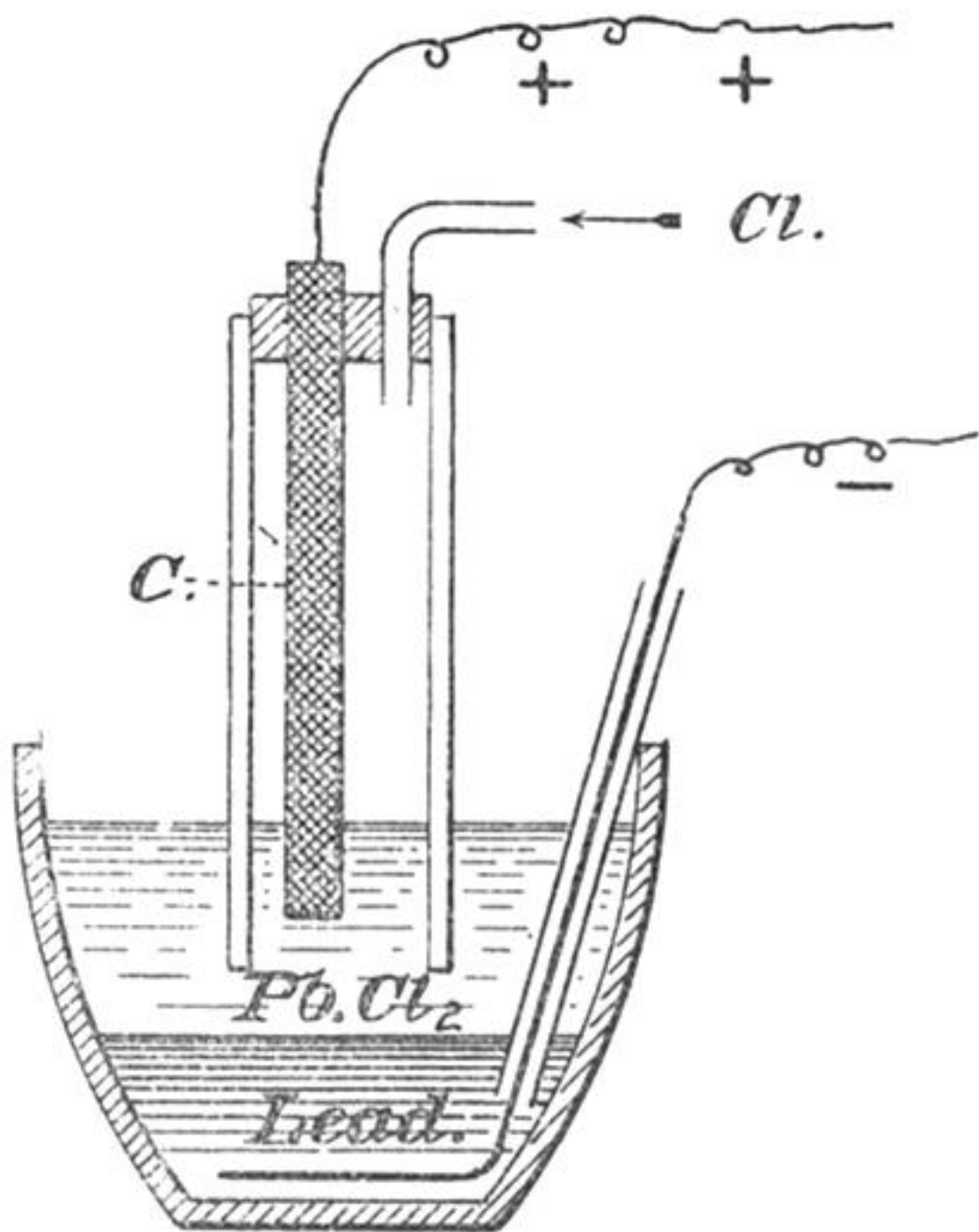


FIG. 6.

